WOODS HOLE OCEANOGRAPHIC INSTITUTION

Reference No. 60-25

DEVELOPMENT OF SOUND ANALYSIS EQUIPMENT FOR SONAR RESEARCH, PART II

WOODS HOLE, MASSACHUSETTS

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DEVELOPMENT OF SOUND ANALYSIS EQUIPMENT FOR SONAR RESEARCH, PART II

by

Lincoln Baxter, II

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APPROVED FOR DISTRIBUTION Paul M. Fye
Paul M. Fye, Director

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I. INTRODUCTION

1.1 Late in 1955 the Deep Water Propagation Committee recommended procurement of 10 sets of sound analysis equipment to be distributed to laboratories working in the field of underwater acoustics. This recommendation was made to be one of the objectives of Contract Nonr-2129. The equipment, including filters for spectrum analysis, was to compute the time integral of the square of the filter output voltages as discussed by Officer and Dietz (1953), WHOI Ref. No. 53-46. In view of the fact that correlation studies are becoming more important it was recommended that the equipment have an optional mode of operation in which it could compute the time integral of the product of two voltages. Multi-channel computers were recommended because analysis of data from one hydrophone for one frequency band at one time is much too slow in view of the large amount of data to be processed. Eight channels per computer were chosen because this is the largest number available in standard direct-writing recorders.

1.2 The history of this project up to March 1958 is given in WHOI Ref. No. 58-12, and concludes with the selection of Electronic Associates of Long Branch, New Jersey, to build the computers.

1.3 Since March 1958, two engineering prototype computers have been delivered by Electronic Associates. The first, a two-channel prototype, was ordered in January and received in June of 1958. The second, an eight-channel prototype, was ordered in September 1958 and received in May 1959.

1.4 These engineering prototype computers have been used for numerous analysis of transmission and reverberation data. In many cases the analyses have been completed in the field and preliminary reports giving the scientific results of the measurements have been circulated within days or weeks of the time that the measurements were made. Final reports have been published within six months. With the computers we have had previously it has taken as long as two years to arrive at comparable stages.

1.5 Five production-model eight-channel computers incorporating the minor changes found to be desirable were ordered in July 1959 and are now scheduled for delivery to the Woods Hole Oceanographic Institution between January 20 and February 20, 1960.

II. DESCRIPTION OF ELECTRONIC ASSOCIATES OCEANOGRAPHIC COMPUTOR MODEL 45. 001

2. 1 The Electronic Associates Oceanographic Computor Model 45. 001 (Fig. 1) occupies a six-foot relay rack, and consists of four dual-channel units, a control panel with stored overload indication, and four power supplies. A model 158-100B eight-channel Sanborn recorder (without amplifiers) mounted in a model 158-1100R cabinet and eight Allison filters, four model 2-AR and four model 2-BR, are additional equipment to be supplied under contract Nonr 2129-5. A computing set-up employing these components is shown in Fig. 2. The Allison filters are in the rack on the extreme left, the 45. 001 computer is on the extreme right, and the Sanborn recorder is next to the computer. The control panel of the computer is missing in Fig. 2 because it had been returned to Electronic Associates for modification at the time the photograph was taken.

2. 2 The entire computer, including the Sanborn recorder, will operate on a single 20 amp, 115 volt, AC circuit.

2. 3 The eight-channel computer divides conveniently into separate two-channel modules that can be used to drive two Sanborn styli anywhere that two channels of computation are required. The separate power supplies also prevent interaction between separate channels in the complete computer. When a module is operated without the common control panel, separate monitoring equipment and a keyable source of minus 60 volts must be provided. A dual channel oscilloscope and a battery and telegraph key have been used by the Woods Hole Oceanographic Institution.

2. 4 The computer will operate correctly over a wide range of input levels. Attenuation from zero to 60 decibels in three decibel steps is provided for each input. If the optimum attenuator settings for a given signal are used, signals with peak levels between three millivolts and ten volts may be accommodated with five percent accuracy. Signals having a peak level anywhere within a ten-decibel range are considered to be correctly accommodated with a single attenuator setting. That is, five percent accuracy will be achieved. Results may be useable if the peak is within a 30-decibel range. For signals greater than or smaller than the limits of the 30-decibel range of a given attenuator setting the response of the computer becomes much less than the correct value. For example, with

minimum attenuation, five percent accuracy is achieved for signals with peak levels between three and 10 millivolts. Results with this setting may be useable, however, if the peak level is between 0.5 and 30 millivolts. The accuracy of the levels actually used will be indicated on the monitor panel which will store indications of peak values until manually reset.

2.5 A wide range of input signal frequencies will be computed correctly. Response of the production models should be flat from 10 cycles to 40 kilocycles. This is achieved by use of powerful preamplifiers with air-core transformers. Fig. 3 shows the frequency response of these amplifiers when supplying 20 volts peak to peak to a 600 ohm load.

2.6 The computer is supplied with the input connected for a 600-ohm line with one side grounded. Since the preamplifiers are excellent differential amplifiers it is a relatively simple matter to modify the input connections to suit 600-ohm balanced or floating lines.

2.7 A great variety of useful functions of the input potentials may be obtained by use of the computer. The functions that may be obtained from each two-channel module are outlined in Table I. Each module operates simultaneously upon input potentials A (t) and B (t) and drives two Sanborn styli. The deflections of the styli are referred to as D_1 (t) and D_2 (t) respectively. For most settings of the computer D_1 (t) is a function of A (t) only and D_2 (t) is a function of B (t) only. However, functions of the product of A (t) and B (t) may be obtained from D_1, and functions of the sum of the squares of A (t) and B (t) may be obtained from D_2.

2.8 Table I is constructed to show the stylus upon which a possible function may be presented. When the proper controls are operated, the deflection of the indicated stylus will equal the function on the left with the value of G indicated at the top. For example function 4b is

$$D_1 = \frac{2f}{\alpha \tau_0} \int_{t_0}^{t} \left[N + \frac{A^2(t)}{\gamma_1^2} \right] dt$$

2.9 The symbols used in Table I have the following meanings:

α = integrator attenuation factor (10 log α = I where I is the decibel or logit setting of the integrator in 10 steps from 0 - 30 in present production models).

TABLE I

FUNCTIONS AVAILABLE FROM A MODULE OF THE MODEL 45.001 OCEANOGRAPHIC COMPUTER

	a	b	c	d	e	f	
D(G) \ G	$\frac{\lvert A(t)\rvert}{\gamma_1}$	$\frac{A^2(t)}{\gamma_1^2}$	$\frac{\lvert B(t)\rvert}{\gamma_2}$	$\frac{B^2(t)}{\gamma_2^2}$	$\frac{A(t)B(t)}{\gamma_1\ \gamma_2}$	$\frac{A^2(t)}{\gamma_1^2}+\frac{B^2(t)}{\gamma_2^2}$	
$\frac{2f\beta e^{-\frac{t}{\tau}}}{\tau}\int_{t_o}^{t}(N+G)e^{\frac{t}{\tau}}dt$	D_1	D_1	D_2	D_2	—	D_2	1.
$\frac{f\beta e^{-\frac{t}{\tau}}}{\tau}\int_{t_o}^{t}(N+G)e^{\frac{t}{\tau}}dt$	—	—	—	—	D_1	—	2.
$15+K\,\text{logit}\left[\frac{\beta e^{-\frac{t}{\tau}}}{L\tau}\int_{t_o}^{t}(N+G)e^{\frac{t}{\tau}}dt\right]$	D_1	D_1	D_2	D_2	—	D_2	3.
$\frac{2f}{\alpha\tau_o}\int_{t_o}^{t}(N+G)\,dt$	D_1	D_1	D_2	D_2	—	D_2	4.
$\frac{f}{\alpha\tau_o}\int_{t_o}^{t}(N+G)\,dt$	—	—	—	—	D_1	—	5.
$15+K\,\text{logit}\left[\frac{1}{\alpha L\tau_o}\int_{t_o}^{t}(N+G)\,dt\right]$	D_1	D_1	D_2	D_2	D_1	D_2	6.

β = decay constant = 10 in present production models.

γ = preamplifier attenuation factor (20 log γ = P, where P is the decibel setting of the preamplifier in 20 steps from 0 to 60 in the present production models).

f = basic scale constant of the computer(depends upon whether quadratic or absolute value type function is selected) = 4×10^3 mm/volt for absolute value and 5×10^5 mm/volt^2 for quadratic type functions in present production models.

L = basic reference level of the computer (depends upon whether quadratic or absolute value type function is selected) = 2×10^{-4} volts for absolute value and $(10^{-3}\text{ volts})^2$ for quadratic type functions.

k = scale constant of the logarithm = 2 mm/logit for quadratic type functions and 1 mm per logit for absolute value type functions in present production models.

τ_0 = basic integration time of the computer = 0.001 second in present production models.

τ = sampling time = $\alpha\beta\tau_0$ (varies from 0.01 second to 10 seconds in present production models).

t = time (independent variable)

t_0 = initial time (time when computation begins)

N = noise cancellation setting.

2.10 The way in which these functions are derived is shown in the block diagram of a computer module, Fig. 4. The outputs of the A. C. preamplifiers give plus and minus values of the amplified inputs. These amplifier signals are applied to various diode function generators to obtain the absolute values, squares and products. The desired functions are selected by switching to the output of the appropriate function generator. Integration and addition is performed by a high gain D. C. amplifier with capacitive feedback. Integration may be performed with or without a decay constant. The functions in the first three rows of Table I are integrated with a decay constant. Those in the last three rows are integrated without a decay constant. Decay constant integration gives, at any instant, an average value over the preceding time interval, τ. The time interval τ is known as the sampling time. To integrate without a decay constant pure capacitive feedback is used. To integrate with a decay constant the feedback capacitor is shunted with a resistor. The output of the integrating D. C. amplifier is supplied to a logarithmic diode function generator and a resistor. Either the output of the diode function generator or that of the resistor is switched to the input of the final D. C. amplifier to select the logarithmic or linear function as required. The final amplifier and its associated components is used to supply the power and adjust the scale factor to drive the Sanborn stylus.

2.11 Integrator limits and reset control are also shown in Fig. 4. To prevent overload of the integrating D. C. amplifier, a limiting network is used which, if the limits are exceeded, shunts the capacitor with feedback resistance effectively one fiftieth that used for decay constant. To reset the integrators for t_0 a resistance one-thousandth that used for the decay constant is connected across the capacitor by a relay. While the limit network and the reset relay are returned to the summing point through the same resistor, the resistances in the limit network itself cause the effective resistance that appears across the capacitor to be different. Limits of plus and minus one hundred volts are used for products and for certain checks. For all other functions the limit clamp switches are set to "on" to make the limits plus one hundred and zero volts.

2.12 The location of the controls is shown in Fig. 5 which is a photograph of the front panel of a dual-channel module from the eight-channel engineering prototype. The production models will differ in minor details from the model shown. A course and fine dial for the noise cancellation setting for each channel have been provided for the production models making a total of four noise cancellation dials instead of two on the module panel. Daven attenuator dials for the input attenuators on the left have been substituted for those shown printed in the front panel.

III. APPLICATIONS OF THE MODEL 45.001 COMPUTER

3.1 On account of its accuracy, bandwidth and versatility the 45.001 computer should have great usefulness as a data recording system for steady state and transient signals where Fourier components, cross-correlations, auto-correlations, and rectified average amplitudes are being studied. It alone will perform the functions of several recording systems that are widely used, as well as many other functions for which no such versatile machine is currently available. The difficulties of operating it in the field are only slightly greater than those of operating a standard Sanborn driver system.

3.2 Many of the functions derived by the computer have already proven their usefulness in underwater acoustic research. Within the last eight years most of the acoustic spectra reported by WHOI investigators for experiments with explosive sources have been measured with computing equipment designed to derive functions 4b and 4d. The principal reason for developing the computer was the desire to obtain better equipment for deriving these functions. Use of this type of equipment was pioneered at WHOI by Officer and Dietz (1953). Since then similar equipment has been used by other laboratories. Equipment to present functions 1a and 1c has an even longer history. Rectified galvanometer traces were used to present the high frequency components of explosive signals by Worzel and Ewing in 1943. A basically similar presentation was used even earlier by the U. S. Coast and Geodetic Survey for radio acoustic ranging. A rectified driver for Sanborn type recording was developed at the Woods Hole Oceanographic Institution by W. Dow in 1948 and has been widely used since then. The Sanborn Log Audio preamplifier became available in 1954. In addition to the functions 1a and 1c the Log Audio preamplifier can present functions 3a and 3c. With the advent of the latter instrument use of functions 1a, 1c, 3a and 3c became almost universal in laboratories working in underwater acoustics.

LIST OF FIGURES

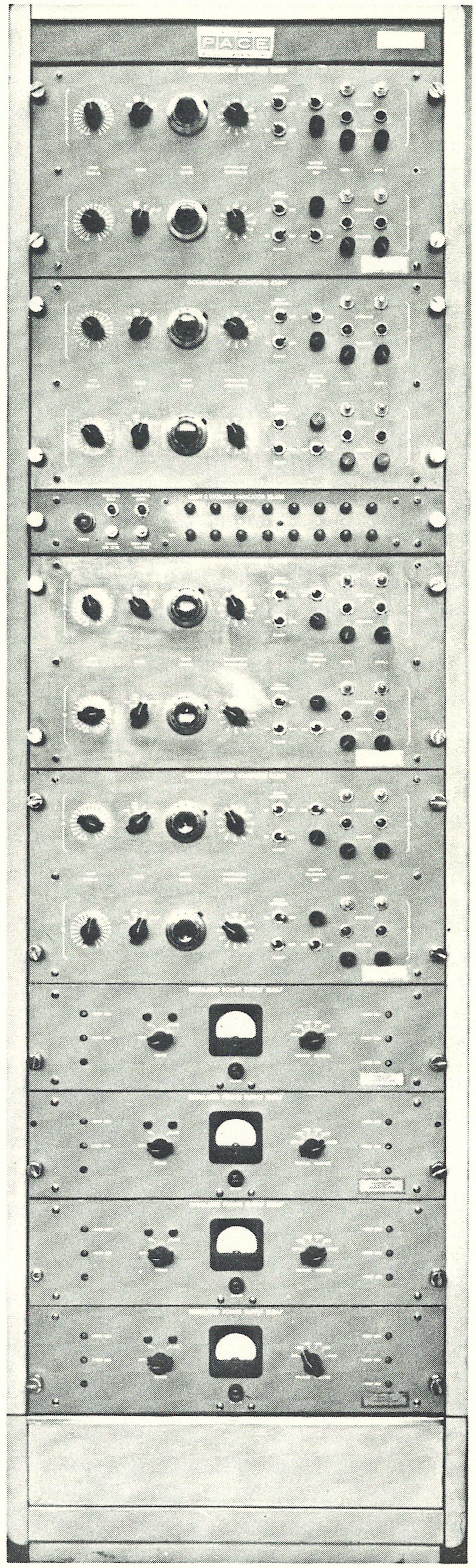

FIGURE 1. FULL LENGTH PHOTO OF 6 FT. RACK OF 45.001 COMPUTER.

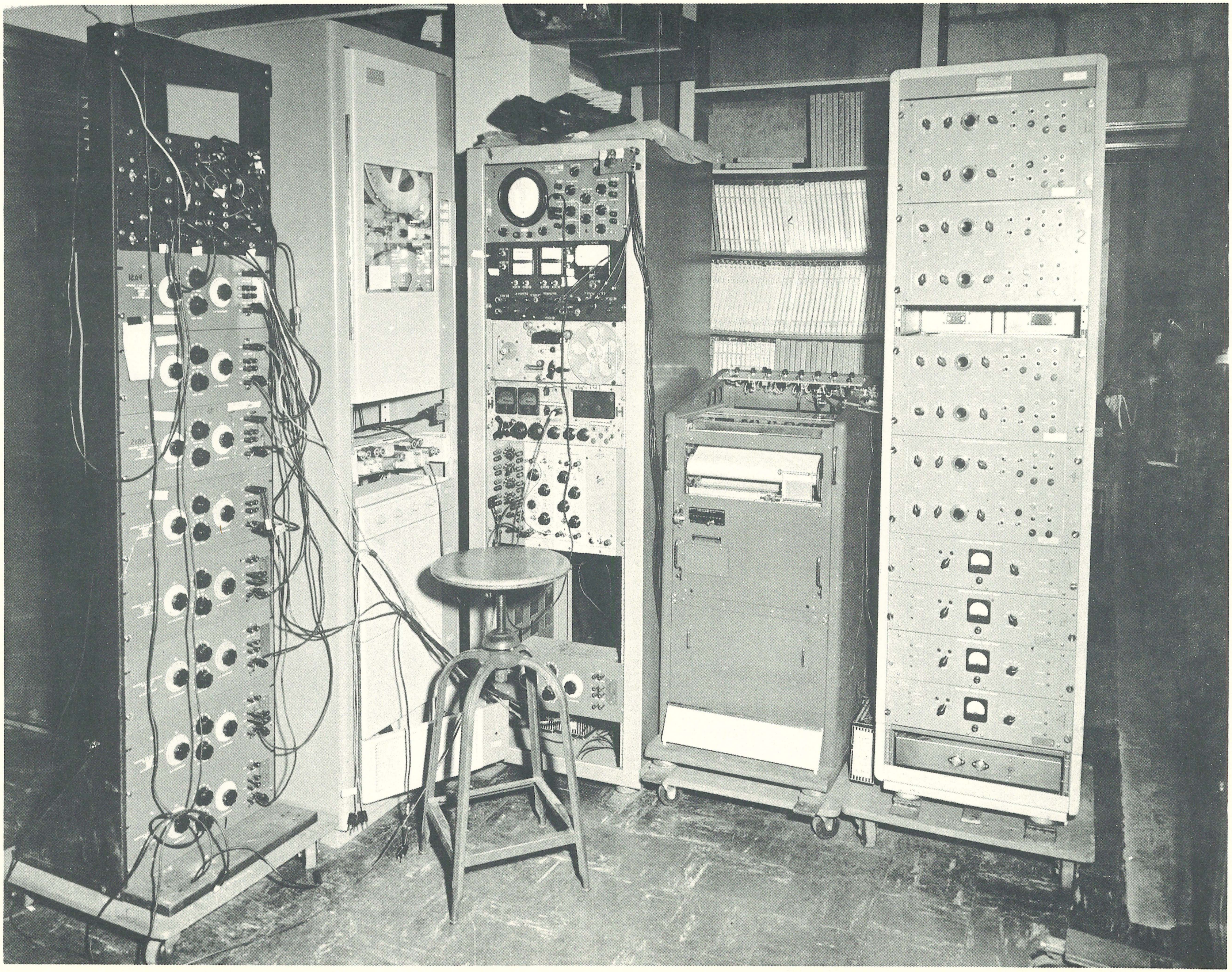

FIGURE 2. PHOTO OF COMPUTING SET UP WITH OTHER COMPONENTS.

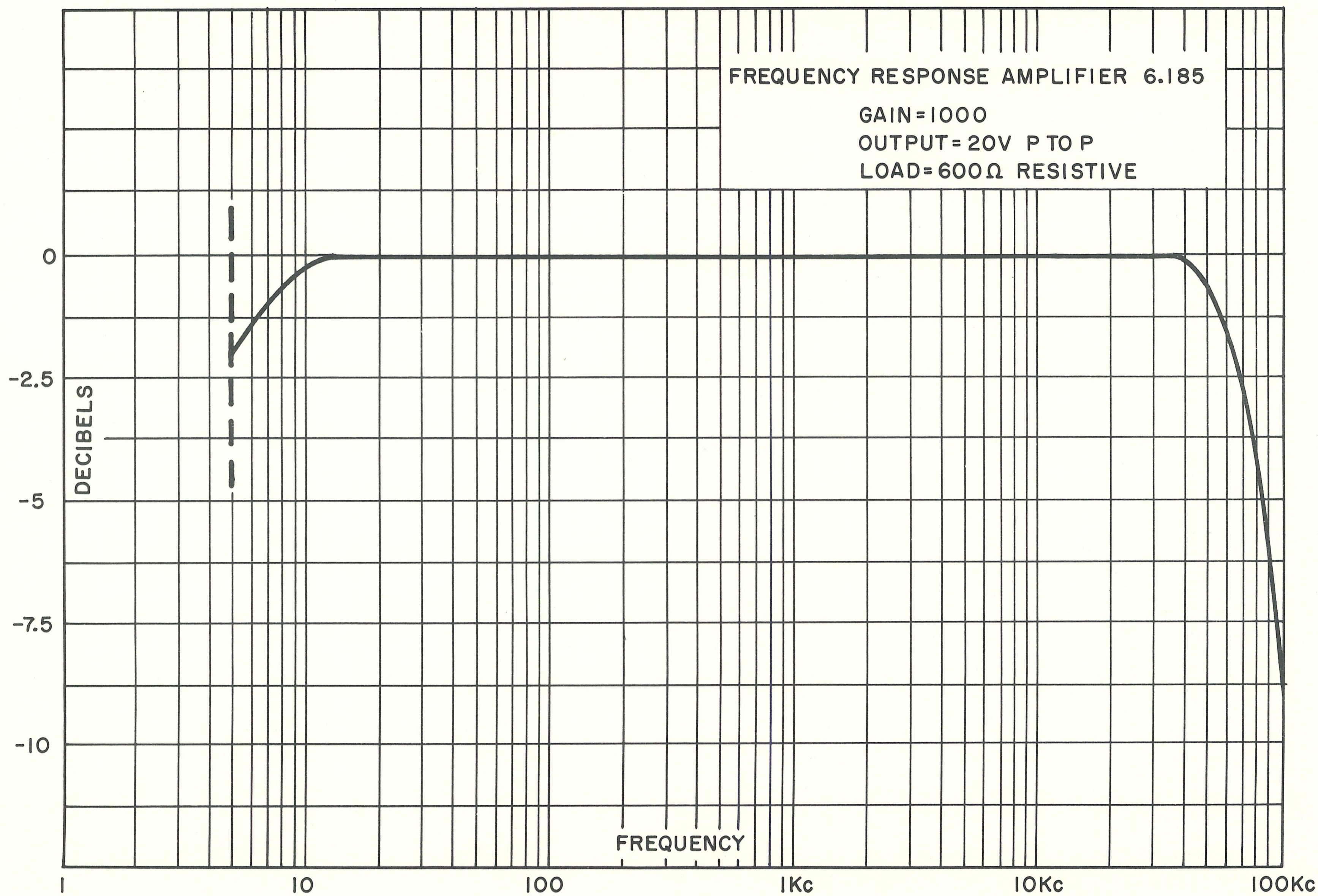

FIGURE 3. FREQUENCY RESPONSE OF COMPUTER PREAMPLIFIERS.

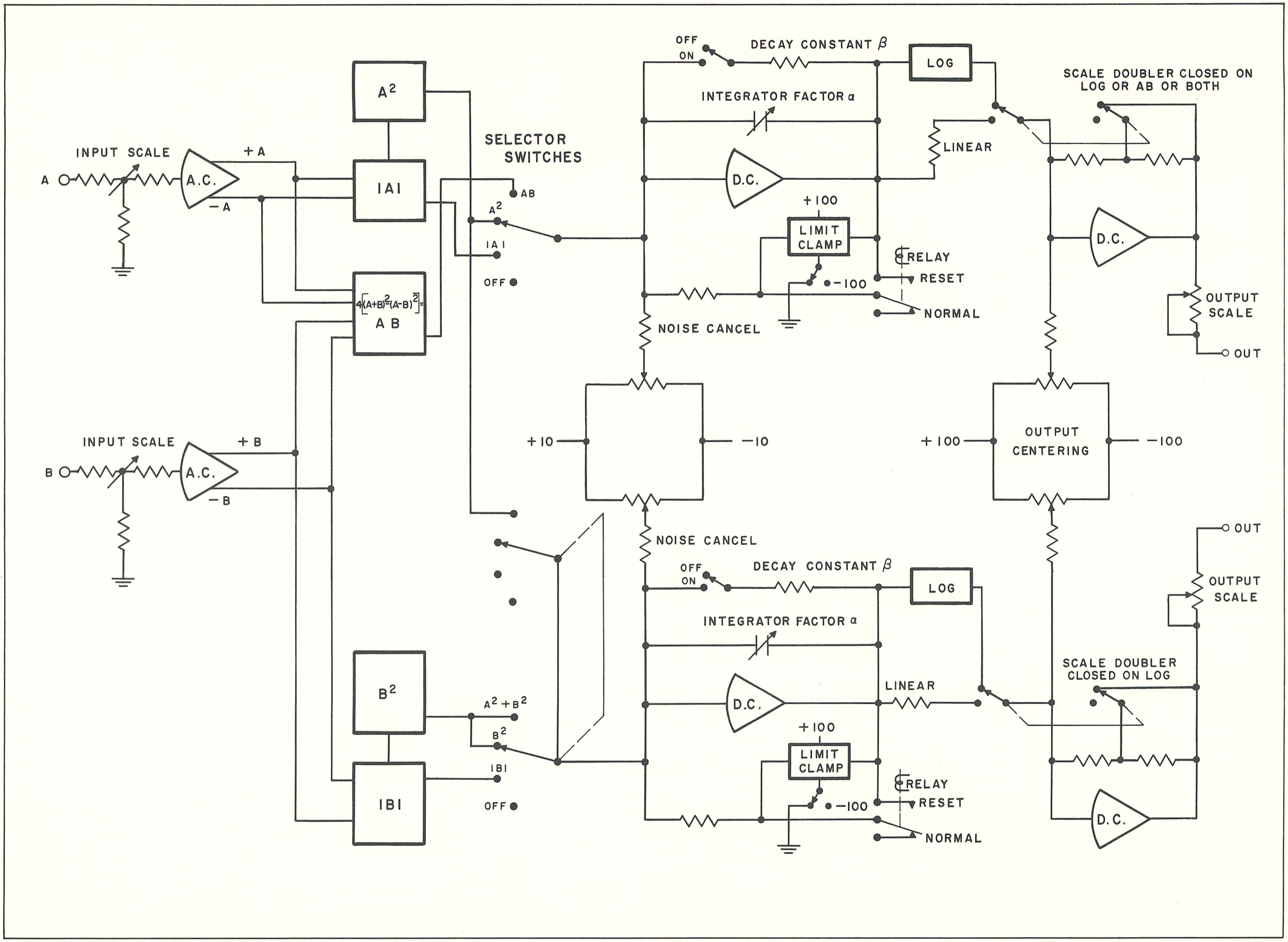

FIGURE 4. BLOCK CIRCUIT OF COMPUTER MODULE.

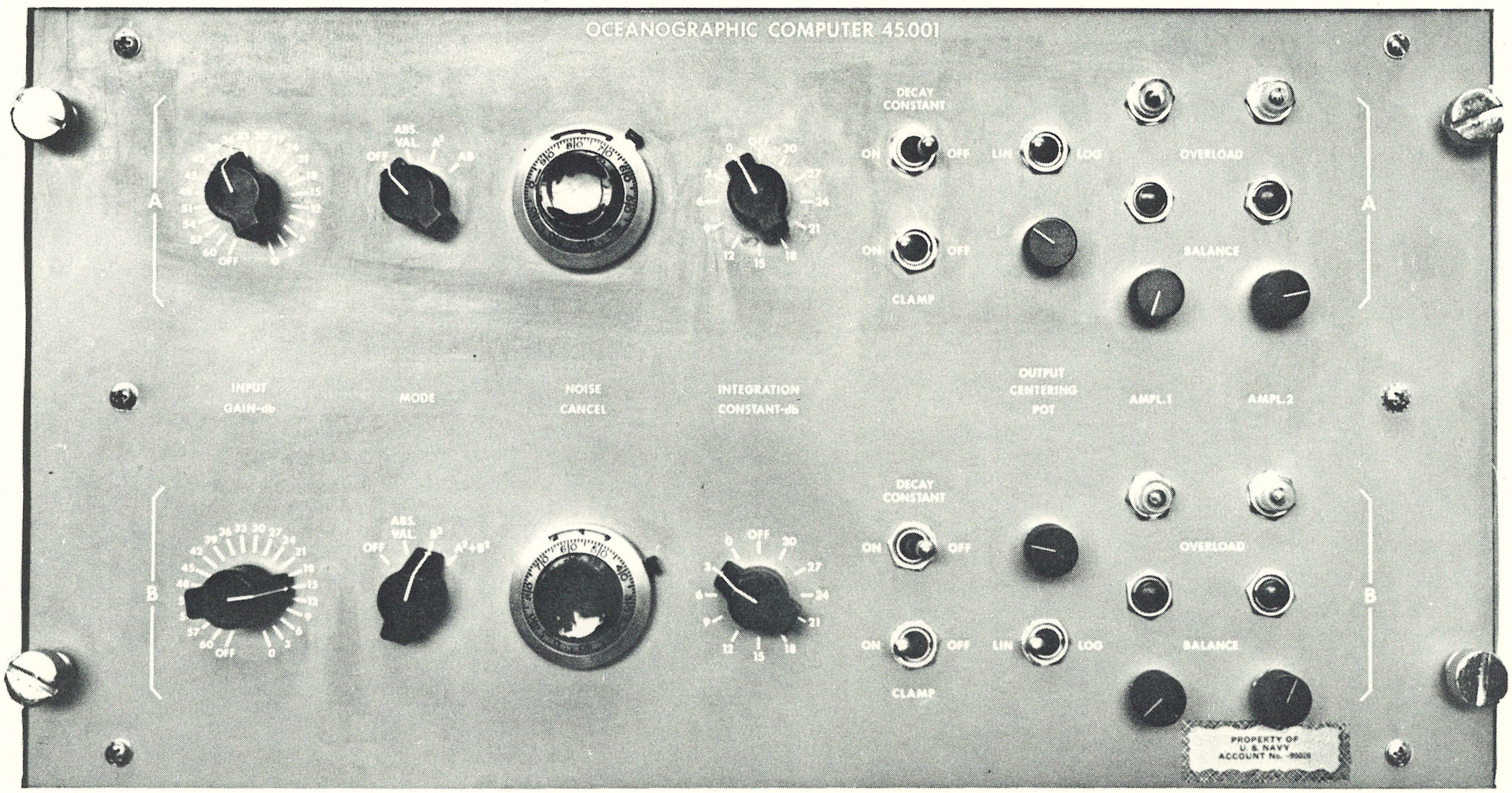

FIGURE 5. PHOTO OF FRONT PANEL OF COMPUTER MODULE.

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